



## **Fuels Containing Methane or Natural Gas in Solution**

**A blend of gasoline and natural gas offers advantages over alternative fuels.**

*Lyndon B. Johnson Space Center, Houston, Texas*

While exploring ways of producing better fuels for propulsion of a spacecraft on the Mars sample return mission, a researcher at Johnson Space Center (JSC) devised a way of blending fuel by combining methane or natural gas with a second fuel to produce a fuel that can be maintained in liquid form at ambient temperature and under moderate pressure. The use of such a blended fuel would be a departure for both spacecraft engines and terrestrial internal combustion engines. For spacecraft, it would enable reduction of weights on long flights. For the automotive industry on Earth, such a fuel could be easily distributed and could be a less expensive, more efficient, and cleaner-burning alternative to conventional fossil fuels.

The concept of blending fuels is not new: for example, the production of gasoline includes the addition of liquid octane enhancers. For the future, it has been commonly suggested to substitute methane or compressed natural gas for octane-enhanced gasoline as a fuel for internal-combustion engines. Unfortunately, methane or natural gas must be stored either as a compressed gas (if kept at ambient temperature) or as a cryogenic liquid. The ranges of automobiles would be reduced from their present val-

ues because of limitations on the capacities for storage of these fuels. Moreover, technical challenges are posed by the need to develop equipment to handle these fuels and, especially, to fill tanks acceptably rapidly. The JSC alternative — to provide a blended fuel that can be maintained in liquid form at moderate pressure at ambient temperature — has not been previously tried.

A blended automotive fuel according to this approach would be made by dissolving natural gas in gasoline. The autogenous pressure of this fuel would eliminate the need for a vehicle fuel pump, but a pressure and/or flow regulator would be needed to moderate the effects of temperature and to respond to changing engine power demands. Because the fuel would flash as it entered engine cylinders, relative to gasoline, it would disperse more readily and therefore would mix with air more nearly completely. As a consequence, this fuel would burn more nearly completely (and, hence, more cleanly) than gasoline does.

The storage density of this fuel would be similar to that of gasoline, but its energy density would be such that the mileage (more precisely, the distance traveled per unit volume of fuel) would be greater than that of either gasoline or

compressed natural gas. Because the pressure needed to maintain the fuel in liquid form would be more nearly constant and generally lower than that needed to maintain compressed natural gas in liquid form, the pressure rating of a tank used to hold this fuel could be lower than that of a tank used to hold compressed natural gas.

A mixture of natural gas and gasoline could be distributed more easily than could some alternative fuels. A massive investment in new equipment would not be necessary: One could utilize the present fuel-distribution infrastructure and could blend the gasoline and natural gas at almost any place in the production or distribution process — perhaps even at the retail fuel pump. Yet another advantage afforded by use of a blend of gasoline and natural gas would be a reduction in the amount of gasoline consumed. Because natural gas costs less than gasoline does and is in abundant supply in the United States, the cost of automotive fuel and the demand for imported oil could be reduced.

*This work was done by Thomas A. Sullivan of Johnson Space Center. For further information, contact the Johnson Commercial Technology Office at (281) 483-3809. Refer to MSC-22873.*

## **Direct Electrolytic Deposition of Mats of $Mn_xO_y$ Nanowires**

**These mats of nanowires can be used as electrodes for batteries and capacitors.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

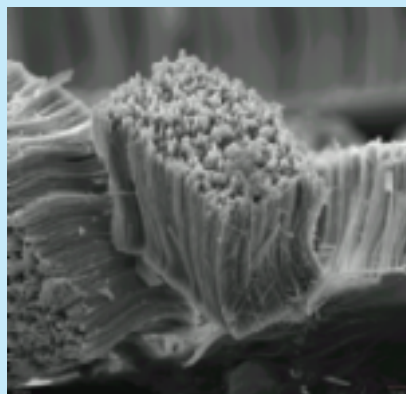
Mats of free-standing manganese oxide ( $Mn_xO_y$ ) nanowires have been fabricated as experimental electrode materials for rechargeable electrochemical power cells and capacitors. Because they are free-standing, the wires in these mats are electrochemically accessible. The advantage of the mat-of-nanowires configuration, relative to other configurations of electrode materials, arises from the combination of narrowness and high areal number density of the wires. This combination offers both high

surface areas for contact with electrolytes and short paths for diffusion of ions into and out of the electrodes, thereby making it possible to charge and discharge at rates higher than would otherwise be possible and, consequently, to achieve greater power densities.

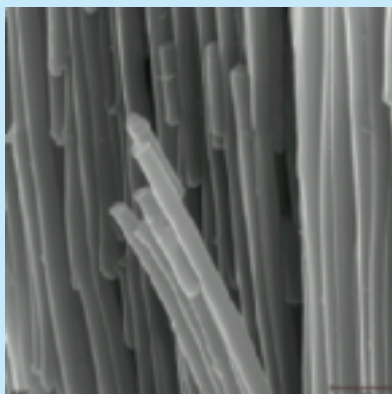
The nanowires are fabricated in an electrolytic process in which there is no need for an electrode binder material. Moreover, there is no need to incorporate an electrically conductive additive into the electrode material; the only

electrically conductive material that must be added is a thin substrate contact film at the anchored ends of the nanowires. Hence, the mass fraction of active electrode material is close to 100 percent, as compared with about 85 percent in conventional electrodes made from a slurry of active electrode material, binder, and conductive additive pressed onto a metal foil.

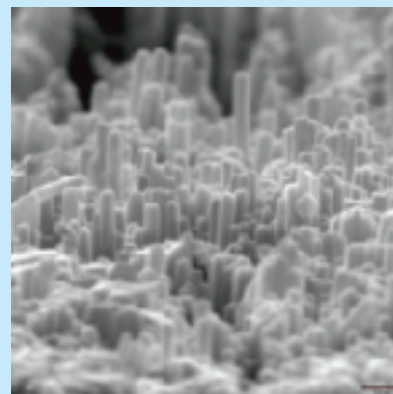
The locations and sizes of the nanowires are defined by holes in templates in the form of commercially avail-



Cross-Sectional View (Low Magnification)



Cross-Sectional View (High Magnification)



Top View

These **Free-Standing  $Mn_xO_y$  Wires** were made by electrodeposition of  $Mn_xO_y$  in 20-nm-wide pores in an alumina membrane, then dissolving the membrane in a concentrated alkaline solution.

able porous alumina membranes. In experiments to demonstrate the present process, alumina membranes of various pore sizes and degrees of porosity were used. First, a film of Au was sputtered onto one side of each membrane. The membranes were then attached, variously, to carbon tape or a gold substrate by use of silver or carbon paste. Once thus attached, the membranes were immersed in a plating solution comprising 0.01 M  $MnSO_4$  + 0.03 M  $(NH_4)_2SO_4$ . The pH of the solution was kept constant at 8 by addition of  $H_2SO_4$  or  $NH_4OH$  as needed.  $Mn_xO_y$  nanowires were poten-

tially electrodeposited in the pores in the alumina templates. Depending on the anodic deposition potentials,  $Mn_xO_y$  was deposited in various oxidation states [divalent ( $Mn_3O_4$ ), trivalent ( $Mn_2O_3$ ), or tetravalent ( $MnO_2$ )]. The  $Mn_xO_y$  wires were made free-standing (see figure) by dissolving the alumina templates, variously, in KOH or NaOH at a concentration of 20 volume percent.

*This work was done by Nosang Myung, William West, Jay Whitacre, and Ratnakumar Bugga of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).*

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